SCIENCE AND TECHNOLOGY IN INDIA
A Preview of 1975

THOUGH the Renaissance ushered in the age of scientific thought and outlook several centuries ago, intense scientific progress has been achieved only in the past hundred and thirty-five years. During this period science and technology made rapid progress. Indeed, its development in recent years has been so phenomenal that scientific knowledge has almost been doubling itself every ten years. This progress has made a great impact on all aspects of civilized life thus making science and its application to technology the most vital activities of the modern age and what was once largely a private affair has now become a public concern. In this enlightenment the two great world wars seem to have played a major part. For forecasting possible trend of events in the near future it is necessary to understand the immediate past and the present; the future will to a large extent be a projection of these with necessary modifications.

SCIENCE AND TECHNOLOGY IN THE PAST

In the last century there was very little of science in India. People studied mathematics, but it was pursued as an arts subject. It was considered to sharpen the intellect and was found useful to some extent for surveying and for civil engineering. Physics was also studied in an elementary way, but there was very little of chemistry or biology. Practically all engineers and technicians required by Government were foreigners. For railways, roadways and military needs all machines were imported and only limited skill was developed locally for maintenance and operation. Hardly any large scale industry existed, cottage industries were traditionally carried on in their homes by artisans who had inherited skill.

Spinning and weaving were common in villages which produced good quality textiles. Similarly, in metal works (smithy of iron and silver and gold) also there was considerable individual skill known for generations. More organized were tobacco factories but they too were again on a cottage scale. The country was indeed in the agricultural and rural age. The prevailing idea was that it cannot be otherwise. It cannot develop industries simply because it was thought that there was no coal or iron in the country. Even if small amounts of either of these were discovered, one was too far away from the other, to be effective. Since there was no industry, there was no use for science. India had a good philosophical and religious bent of mind. Bright and intelligent Indians were expected to cultivate these and contribute their share to world culture.

India slowly lost whatever industrial market she possessed in the past. Vegetable dyes like, blue indigo and the red chaya had been produced in India from time immemorial and exported to Europe. In the second half of last century Europe developed synthetic chemistry and the synthetic dyestuffs industry. Slowly indigo cultivation and the indigo vats became obsolete and so also other indigenous dyes, and we got accustomed to the supply of synthetics for our dyers because they are cheaper and also available in greater variety. Even for religious festivals like the Holi vegetable dyes came to be discarded. Similarly, cultivation and use of vegetable drugs also became slowly obsolete and modern synthetic drugs and antibiotics more fashionable.

In the early decades of the 20th century the British Government was desirous of improving the scientific education of the Indian people. As the result some of the advances in British education in the science were brought in. Several enthusiastic teacher-scientists were located in important university centres like Calcutta, Dacca, Madras, Bangalore, Bombay and Lahore, who were able to stimulate interest in modern science. Even then science was studied as a training of the mind and faculties, not for its utility or for the benefit of society. Neither was it thought that it could be developed further in the field of research or for the improvement of technology. For these reasons, most Professors of Science regarded Research as a waste of time.

It should here be mentioned that for the far flung Empire of the British, India occupied a central or key position and certain military industries had to be strategically located here. This became vastly important during the First World War. Munitions Board was set up and extended and to man them scientists were trained. I remember the starting of a glue factory at Madras in which a chemistry graduate

was employed till he passed a competitive examination and entered Accounts and Audit Service. Some others entered the developing tanning industry. The most important advance was in the production of textiles, rubber, vegetable drugs and dyes which were in short supply. That war was a critical period for it showed how poorly equipped India was in science and technology in spite of its large population and intelligent people. Though we supplied good soldiers and medical men, it would have been far better if we also had good training in science and technology and could supply scientists and technologists. However at the close of the War, the Government made special effort to fill the need and expert committees were set up for this special purpose. Scholars were also sent abroad for special training even if their numbers were small. They were mainly instrumental in the building up of science and of organizing scientific research and technology in India. But unfortunately this was also a period of great political agitation which engaged the minds of people and of the Government. Therefore, during this post-World War I period development of science and technology was not as impressive as it would have been otherwise. However, several new Universities were opened with emphasis on the teaching of science and several technological institutes and factories mainly devoted to textiles, jute and sugar were built and operated. Otherwise, our progress during the 20 years between the two Wars was small.

The Second World War like the first was again an eye opener revealing how backward we still were in science and technology. This war was more intense and part of it was fought in our country. Modern warfare, as is too well known, requires not only strong and brave soldiers, but also the sustained support of science, engineering and technology and of heavy industry. Unless a country is well developed in all these respects it cannot engage in a modern war for any length of time. During the Second World War, the Board of Scientific and Industrial Research was organized (now, CSIR, *i.e.*, Council of Scientific and Industrial Research), many colleges of Engineering and Technology were opened and similarly a large number of Polytechnics. The end of the War brought the long cherished political independence and India became free to determine her own destiny. This was an event of great importance.

One of the earliest steps the popular government took in India was to develop science and technology and thus overcome the existing handicaps in this direction. Under somewhat parallel circumstances about 30 years earlier the Soviet Rulers led by Lenin appreciated the vital importance of science for sustaining the Revolution and gave it

extraordinary encouragement with the result that Russia in a short span of time became a leader rivalling Germany, U.K. and U.S.A. in the scientific field. This was quite unexpected when we think of the short period and the difficult conditions under which they have done it. Somewhat similar support has been given to science in post-independence period in India. Large number of scholars have been sent abroad for training, and large grants have been provided for engineering and technological education. In the successive five year plans scientists have been drafted in large numbers not only for the developing major industries, engineering, textile and chemical, but also for the fast growing research institutions in science and technology. Several National Laboratories have sprung up along with a number of industrial laboratories. The Atomic Energy Establishment has been growing fast, so also the laboratories relating to defence needs. The result is that we are making rapid progress though it is not as fast as the leading industrial countries like U.S.A., U.K. and Russia, for they started much earlier than us and have had a longer experience. Besides, we have to develop a tradition in Scientific Research which takes time and does not happen overnight. Unfortunately, our political freedom has not been accompanied by the continuance of the spirit of sacrifice that had characterized the earlier period of our struggle for freedom. Many of us seem to have been attracted by power and its derived benefits forgetting both the importance of the country's needs and its progress. However in this matter, a corrective has come in the shape of a threat from China and Pakistan. While we undoubtedly have exhibited great unity and sacrifice during the brief border wars we must also realize that they are continuing threats and that we should be constantly vigilant, strong and united. Development of science and technology as a means of service to the motherland, and also for the good of the world should be now the chief incentive and deriving force.

CONTEMPORARY DEVELOPMENTS

University and Other Training Centres

The number of Universities in the country has increased to nearly 65, and further increase is likely. The number of science and technology institutes and students too have multiplied in a spectacular way after Independence; for example, engineering students have increased ten-fold. Science colleges and colleges of engineering and technology, agriculture and medicine and pharmacy have sprung up in large numbers with the special object of training the requisite number of graduates

in these sciences, as are needed by the country for its institutions and rapidly expanding industries. But the chief difficulty is that the expansion has been too fast and the availability of good teachers and of teaching equipment have not kept pace. There has been some neglect also owing to other more pressing demands. In consequence there is general complaint that the standards have gone down considerably. Since India is a comparatively young democracy and traditions have not yet been firmly established by which enlightened public opinion asserts itself and guides the policies and actions of government, State Governments have been prompted to satisfy the popular demand, by increasing quantity (in numbers) which is tangible to the lay people, rather than by improving quality (in terms of standards) which is comparatively intangible. Consequently the number of students, particularly in higher educational levels, have been increased without a parallel increase in the laboratory facilities or equipment. Nor have the necessary finances been provided. In many universities, the staff position is somewhat precarious and senior staff appointments have not been made for years. The University Grants Commission (UGC) has been agitated over this matter and has been attempting to improve the quality of teachers and equipment. This effort has not been fully successful because of lack of co-operation from those immediately responsible for university administration. Unfortunately, most of the State Governments and the people have not yet come to look upon the universities as essential organizations for the strength and enlightenment of the community, nor as vitally important institutions which they should be proud of. On the contrary they seem to regard them as convenient instruments through which they can exercise political power.

At the same time, we have had difficulties of foreign exchange besides others as well. For example, foreign countries have tried to retain our trained men for their own advantage by offering them lucrative employment. The total overall position is that while quantitatively we have improved, qualitatively not appreciably, as far as University education in general is concerned. Another important feature is the question of rival demands for talent within the country. In this competition the universities and teaching institutions that can afford comparatively much less, have had to suffer the loss of the best talent available.

During the past 15 years a large number of engineering and technological institutions have grown up in the country. Besides colleges and departments attached to universities, Institutes of Technology (I.I.Ts.) have been established in four different zones and a fifth in

Delhi itself. They are visualized as huge institutions with comparatively generous provision of land and money. Further, they get large aid from advanced countries such as U.S.A., Russia, Germany and Britain which provide help in terms of equipment and teachers. Each of them has provision for teaching all different branches of Engineering and Technology. Again, they all have provided for strong science departments which are well staffed. Consequently, besides technology they propose to teach the sciences at the higher levels and have already started M.Sc. courses in Chemistry and Physics. They have been given the status of universities with authority to grant their own diplomas and degrees. Thus we may observe that as modern technological universities they have a distinct advantage over conventional universities. However, they have still to establish traditions and carve out a distinctive position in the country's over all educational organization. If they were to organize M.Sc. courses only in applied sciences they might then supplement the work of the universities instead of duplicating them.

Besides the I.I.Ts. there are a large number of regional Engineering Colleges. Though they are less well equipped as compared to I.I.Ts. they are nonetheless big institutions with adequate financial resources, and with assistance in some cases from international sources. However they are still somewhat new institutions and have to establish themselves in the context of our growing demands.

Another new type that has come up is the Rural Agricultural Universities located in a large number of States. They are on the pattern of the Land Grant Colleges of U.S.A. and are intended to develop agricultural sciences. In recent years the food problem as a result of an explosive growth of population has been looming large in India compelling us to get aid from other countries. Our agricultural production which should have marched ahead has not kept pace. The agricultural universities are expected to play a vital role in promoting agricultural education and research directed towards stepping up agricultural production.

The Indian Council of Agricultural Research (ICAR) is one of the many all-India Councils and is more than 30 years old. It has continuously helped the Government of India in the organization of Agricultural Research and in the development and administration of many research institutions relating to important commodities such as rice, potato, wheat, cotton, jute, oilseeds, and sugar, besides the premier Agricultural Research Institute in Delhi. With its help many discoveries and developments have been made. The present food crisis in India has again brought into prominence the need for strengthening

and amplifying the work of the Agricultural Research Council. This is being done and a leading scientist (Dr. B.P. Pal) has been appointed Vice-President of the Council and Director General of Agricultural Research. The ICAR has now become the unified organization for controlling and directing all research schemes and research institutes in various commodities in the place of the Central Government.

Similarly, Medical Colleges have increased in large numbers. Each State has a number of them teaching up to the first degree in Medicine and Surgery. The same difficulties of qualified staff and the lack of equipment and falling standards are experienced here also. There are, however, some Medical institutes which have been upgraded, and provide for post graduate teaching and research. These are somewhat better equipped. Many of them receive gifts of equipment and aid from advanced countries. Besides these, there is a special institution called the All India Institute of Medical Sciences (AIIMS) which is very well provided and enjoys the status of a university. Though originally intended for post graduate studies and research it has taken to under-graduate teaching, also, with a view to augmenting trained medical men and women. However at the moment there is great and continuing need for specially trained medical scientists, and therefore, other post-graduate institutions such as the one at Chandigarh and in other places have been established, besides the research institutions intended for nutrition, virus diseases and cancer.

What has been said above about the ICAR applies to the Indian Council of Medical Research (ICMR). This is also a fairly old organization and was earlier known as the Indian Research Fund Association. It has been working actively over a period of years. Slowly, the importance of Medical Research in all its aspects, is being more and more fully realized. The recent border wars have emphasized the urgency of this need. The work of the ICMR, should also be amplified and its resources augmented in order to enable it to keep pace with the needs of general progress and development of the country.

In the field of science and technology and medicine, it was originally hoped that advanced countries will assist in the training of scientists (who will be available for service in India). On the other hand, things have so shaped themselves that a large majority of our trained personnel is being employed by other countries for their own needs, at the expense of India, which has borne the cost of their training. In this way large number of medically trained are found outside the country and this is a great handicap for a developing nation.

National Laboratories

During the last World War, for its efficient and successful prosecution, the help of science was needed. There were a number of directions in which research and its applications were used. The Board of Scientific and Industrial Research was organized for this purpose and it had its laboratories both for chemical and physical studies located first in the Alipore Test House at Calcutta and later, after the bombing of that city by the Japanese, they were removed to Delhi and located in the Delhi University. Dr. S.S. Bhatnagar was the founder-director and he and his colleagues contributed a great deal to the war effort. It was during this period that the idea of National Laboratories to do applied scientific research and help the development of industries was mooted and as soon as India gained Independence it was implemented with great speed and enthusiasm. The Board was changed into the CSIR with a great deal of autonomy and had the Prime Minister Nehru as its President. With his continued help Dr. Bhatnagar could move fast in establishing a nationwide chain of National Laboratories. He argued that since it will take time to develop universities for this purpose, establishment of new and big laboratories was essential. The National Chemical Laboratory at Poona and the National Physical Laboratory at Delhi were the earliest to be planned and built and manned by eminent scientists with reputation: Dr. McBain F.R.S. and Dr. K.S. Krishnan F.R.S. respectively. He did everything to attract the best men by offering very favourable salaries and conditions of work. This led to pulling out many good scientists from the universities where they were very much needed both for teaching and for fundamental research. In rapid succession a number of National Laboratories were opened almost at the average rate of about two every year and now they number about 30. Many of them are devoted to special industries like Glass and Ceramics, Fuels, Metallurgy, Drugs and Leather. Further there are others, called Regional Research Laboratories which are intended to develop and help the industries of the particular region.

The National Laboratories have been conceived in a big way, built with great speed and well staffed. However the markedly rapid growth along with other factors are responsible for the strength and weakness of these laboratories. Their main strength lies in their resources. But since they lack adequate tradition of scientific research, they are not clear in their objectives. As a result the resources are not brought to bear effectively in producing results. Most of the staff have come with an academic outlook, with no experience of industry; further they are generally new to project work of National importance.

Somehow a feeling has been created in the minds of the public that these laboratories are the sole custodians of research in India and universities should only be doing routine teaching. The idea is confirmed by the comparatively liberal expenditure on National Laboratories and the favoured position they occupy and the comparative neglect of the universities. The point that has been missed is that National Laboratories cannot be substitutes for universities with the result that both types of institutions tend to suffer.

Even before the Second World War certain industries had their own technological laboratories. They related to the cotton, jute and sugar industries and were located in Bombay, Calcutta and Kanpur. Besides there were tea and coffee research stations and laboratories. After Independence the textile industry has organized three important laboratories called ATIRA (Ahmedabad), BITRA (Bombay) and SITRA (Coimbatore). These are financed equally by the industries concerned and the CSIR. They are all doing efficient work in their respective lines.

Another series of institutions that characteristically belong to the post-War and post-Independence period, are the Defence Science Laboratories. Started in a small way they have also increased in number and variety to meet the needs of our defence particularly in the face of threat from China and Pakistan. Under the leadership of two distinguished scientists Dr. D.S. Kothari and Dr. S. Bhagavantam, they have developed steadily. Their objectives are clear and they cater to the defence needs.

Yet another series of institutions of this category are the Atomic Energy Establishments and Laboratories. They also started small and under the guidance of their late director, Dr. H. J. Bhaba F.R.S. have grown during the past 15 years quite steadily and fast. Their work is well defined and consequently their efficiency is greater. They also have some of the best scientists and technologists and offer them probably the best conditions of work in India. They belong to all branches of science. Ours is an atomic age and India is pledged to the use of atomic energy for peaceful purposes. In this we have done well.

Place of Scientists

It may be useful to make an appraisal of the present position of scientists and technologists in the country. Even after the First World War (in the Twenties) there was little employment potential for scientists

and technologists in this country. Compared with Civil Services and Engineering and Railway Services they had very little status. They had only some chances of employment in teaching posts in universities and colleges. This continued till the end of the thirties and a part of the period of the Second World War. As the last War progressed more scientists were in demand and to some extent the supply was considered to be insufficient. Many scientists left teaching and other civilian jobs and joined the defence services because they provided attractive openings. At that time patriotic motive in defence was not prominent because India did not enter the war as a nation. It was in the post-war years and after Independence that there has been an unprecedented encouragement to science. One important factor was that there was an outburst of scientific activity all the world over and junior scientists in various subjects were welcomed in many countries, particularly as teaching assistants and research assistants. Our country wanted and encouraged young men to go abroad for training. Numerous foreign scholarships were awarded. Even within the country post-graduate scholarships and research fellowships were awarded liberally by the Ministry of Education, by the CSIR, UGC, Defence and Atomic Energy departments. At a particular stage it appeared that these benefits were chasing candidates instead of the candidates seeking them. On account of the rapid development of universities, National and other laboratories and industries, scientists have been in short supply and their services held at a premium. Many of them keep migrating towards more and more remunerative posts. Barring universities and colleges with their proverbial poverty, in most government and quasi-government organizations promotions to high posts are comparatively easy. Further, there is a new system of merit promotions by which scientists of ability are promoted to supernumerary posts at higher levels. If they desire still more income they can always move into industry which pays considerably higher salaries. Similarly, administrative posts to which scientists can aspire also carry high emoluments and many are attracted to them. In general taking all circumstances into consideration scientists can be said to be well provided. However, there is need to take stock and see that too much money is not spent on prestige posts and that scientists are properly employed.

In spite of all that has been said above, it is a fact that a large number of Indian scientists are found in other countries in temporary or permanent employment. Efforts have been made to bring them back to utilize their talent and training for the country's welfare. This has not been easy for many reasons. Many have gone abroad on government scholarships, but after their training they have taken

up temporary posts there. As already mentioned owing to large expansion of science and technology and industries in U.S.A., Canada, U.K., Australia and elsewhere they allow immigration of a large number of skilled workers. In these countries our scientists also get considerably higher salaries than they would get here. Higher salaries will be impossible in a comparatively poor country like India which is in the throes of development, inflation and other disabilities though it offers good scope for those who need work. Unfortunately we do not have the costly modern equipment as in advanced countries of the West. For patriotic youth these are not handicaps, but are challenges to be met. Instead of taking this view, many of them wish to take advantage of the situation and ask for impossible conditions. As a matter of fact many of them have developed an attitude of narrow specialization and not the valuable attitude of liberal outlook and wide interest. The Government has instituted a system called "Pool" for temporary placement of returning Indian scientists. It has been operated very liberally. But there is difficulty of attitude and understanding which is causing difficulty in getting these scientists properly placed and utilized.

The problem of "Brain-Drain" from India has been attracting serious attention in recent years. No doubt India had and continues to have a large population. During the last century farmers and unskilled labourers used to be taken to countries like South Africa, Uganda, Fiji and Ceylon for agricultural development and most of them have settled there on the fertile lands they were responsible for cultivation. Along with them Indian traders and lawyers also went. Though politically their situation is bad, economically they seem to be well off. A different situation has developed during this century, particularly in post-war years. A large number of Indian scientists and engineers and medical men have been employed in the advanced countries of the world. It is a primary human desire to have the advantage of goods of this world and live comfortably. From time immemorial better developed countries have attracted the more brainy and enterprising persons. In this manner India too, in her days of greatness, attracted a number of scientists and artists and philosophers to this country. Therefore, intelligent men going to other countries in search of wealth and advantage is not unusual. But it is a serious disadvantage for a fast developing country like ours. We have expanded education and other opportunities of training. They are expensive. But the products of this investment in education and scientific training, migrate and benefit other countries which are becoming further more advanced at our expense. This seriously affects all the well-meant Aid the advanced nations give us in certain directions. Even the Indian

scientists concerned generally do not realize what a great loss they impose on the country. There is a duty to serve the country of their birth and develop it without attempts to bargain with it. This duty becomes more important because the country is poor and needs help.

There is another direction in which serious brain-drain occurs within the country. It has so happened that certain vocations such as administration, engineering and medicine are very well paid and offer security of employment. The best brains in the country are attracted to them and only the average have to manage the more original and important avenues of science teaching and scientific research. For example, the best of our school children join engineering courses and the second best the medical courses. These are lucrative in employment potential. However, at the present moment they offer to most of them only work of a routine nature which is not adequate for the high level intelligence of the groups. They are, therefore, in a way under-employed. The fundamental sciences like mathematics, physics, chemistry and biology which provide the base for all advances are depleted of the brains and people with less ability take up the responsibility. Even here the few remaining brainy scientists are drawn towards industries with spectacular emoluments and this for doing work which much lesser men can probably do. Frequently it has become a prestige for the industry to employ men of good name and fame for comparatively lesser needs. This probably happens to some extent in all democratic countries, but the disparity in emoluments between established scientific institutions like universities and industries is not so great elsewhere; it is very marked in India and has serious consequences.

Industries

At the dawn of this century India was solely an agricultural country with no industries of any size, because of the lack of coal and iron. These deficiencies have been made up especially during the last 15 years of independence. Coal has been found in abundance and so also iron and a number of steel plants have been developed as a result of the Five Year Plans and are in operation, though even earlier small steel plants were functioning in different parts of the country. This has enabled the engineering industry producing machines and tools to develop and factories are found in different areas. Agricultural machines are most needed and so also other machines for construction, pumping and transport. They are being produced in increasing quantities. In modern machines, electricity and electronics are very important and the concerned industries have also developed.

For a large country like India the extensive railways constitute a national asset of great value and strategic importance. The mileage was steadily extended and all the railways nationalized. Earlier in this century the rails, and station structures, engines, carriages and waggons and most of the officers were imported. During the past 25 years local production has been encouraged and large workshops have been organized. This along with the large growth of steel and engineering industries is making the country self sufficient. Besides a large number of engineers, scientists are also employed in the maintenance and improvement of various services connected with railway traffic. Road transport originally started by private agencies is being increasingly nationalized and good workshops have been established. More recently motor cars and lorries are being produced in the country for civil and military uses. A similar sequence of changes have taken place in air communications and aeronautical research. Aircraft construction too has been developed to some extent.

Other means of communication like post and telegraph have been under Government control from the beginning. The later introduction of telephones was for some time in the hands of private agencies but was subsequently nationalized. Radio has all along been a Government organization, likewise television, now under rapid development. For the needs of these concerns there are servicing and research laboratories under the Ministry of Communications.

The earliest industry to develop in India was that of textiles. We have been growing a vast amount of cotton and in mediaeval times we used to utilize it by means of efficient cottage industries. Last century raw cotton used to be almost completely exported to industrial countries (U.K.) for conversion into textiles. Attention was directed to this aspect during our struggle for independence. Boycott of foreign cloth and development of Charka were symbolic. The result has been the development of the textile industry on a large scale in Bombay, Ahmedabad, Coimbatore, Madras, Bangalore, Kanpur, Nagpur and Delhi where cotton is easily available. At present this is probably the biggest of our industries. It has now expanded to include synthetic fibres and plastics. Allied to this is the jute industry which has developed largely in Bengal.

Next to textiles is the sugar industry. In the beginning of this century there was mainly crude brown sugar in the country and only a little of purified white sugar was available. New hybrids and varieties of sugar-cane suited for different parts of India have been evolved in research stations and enormous acreage has been covered by them.

Originally the sugar industry was protected and now it is a well developed major industry with sugar factories all over the country. The research institutes and research stations intended for this commodity are adequately to serve its needs.

Organized tanneries were one of the earliest small scale industries, particularly in the South (Madras and Bangalore) and in the East (Calcutta). To meet military needs a centre was developed in Kanpur. They have been steadily growing and large concerns are now in existence. To help this industry, the C.S.I.R. has established a Leather Research Institute at Madras.

Cement industry has been developing fast in our country, but not fast enough to keep pace with the needs of defence, housing and other public demands. But an industry of quite recent origin and of great importance for the near future is the petroleum industry including petro-chemicals. A number of refineries have been established in suitable locations and new petroleum deposits have been discovered. Besides petrol for aviation and motor car, and kerosene for burning we get products capable of yielding polymers, solvents and chemicals when properly utilized. This is a large industry, more important than coal and its proper development should be ensured as early as possible.

From time immemorial drugs used to be made by the physician or druggist on the spot from natural ingredients and dispensed. This continued largely up to the thirties of this century. Later owing to the development of Chemistry and Pharmacy and the discovery of synthetic drugs and antibiotics in a spectacular way on a large scale, the drug trade has become a major industry all over the world. India has moved rapidly in this matter and big production units are established in different parts of the country. Bombay in the West and Calcutta in the East have been the main centres. Recently Hyderabad in central India and Rishikesh in the North have become locations of synthetic and antibiotic plants. There are also special units for the production of vitamins and glandular products and synthetic hormones. These when fully developed will mean major contribution to the nation's health and prosperity. It may be mentioned that even Ayurvedic and Unani drugs are now being produced in certain manufacturing centres on a large scale and distributed.

Related to this category are the food industries. Gone are the days when the housewife used to prepare all food from natural raw materials, grains, vegetables and milk. All food materials receive some processing or other at the hands of the grain miller, oil miller, canning factory

and bread or biscuit industry. Considerable progress has been made to avoide waste and make food safe and cheap. The main demand has been from the defence forces and industrial labour and a number of factories are in operation. In regard to foods and drugs, containers become important and we have suppliers like the Metal Box Company for this purpose.

Chemical industries are large and varied. We had very little before the War. From practically the very start these have been recently developed. The bigger ones relate to dyes and their intermediates and are located in Bombay and Gujarat States. Closely allied and meeting the needs of the textile industry are starch and glucose. Plastics, polymers and rubber form an important group which cater to the needs of structural and transport engineering. Then there are fertilizers, such as ammonium sulphate, urea and phosphates which are of primary need for agriculture. Similar is the importance of insecticides, particularly the synthetic ones to remove agricultural pests and disease bearers like flies, mosquitoes and bugs. But all these have to be backed by the heavy chemical industries producing acids and alkalies and solvents. Though these have been growing, the growth has not been adequate for the needs and this is a handicap.

Glass and ceramics are highly essential for any advance in science and science based industry, particularly chemical industries. We have grown fast in this line and the glass and ceramics research institute at Calcutta has been of great help and has enabled us to produce the best optical glass in the world and has placed our industry in a good position.

Another large industry relates to oils and fats, soaps and detergents. Oils and fats constitute processed foods, and Dalda has become quite popular. Some of the special oils are used in the paints industry and large amounts of others in the manufacture of soaps and detergents. This industry was one of the earliest to develop and there are factories all over the country. There is so much need that there is serious dearth of oils in our country and we import substantial quantities from U.S.A.

From what has been said above it may appear that we are well off industrially, but it is not quite so. We have been developing fast no doubt. But there are major defects. We have not advanced in quality and efficiency. We have been almost abjectly dependent on foreign technical know-how. This is rather serious. Aids and helps are good for placing us on our feet, but unless we develop indigenous

talent and capacity to maintain and develop continuously by research we shall be dragging behind again in the march of progress. There will be economic and scientific dependence which in course of time brings degradation and demoralization. In spite of these defects we are the leaders in these industries in South Asia. However, we have to improve fast and reach world standards, otherwise our efforts will not bear fruit and we shall not be able to stand competition. There is also a tendency to have continued tariff and other forms of import protection for too long a time for both the public and private sectors. This kind of continual protection may be in the long run a handicap for progress and the nation as a whole and the consumers in particular will be the sufferers.

THE FUTURE

To predict the trend of future events or developments for a large country like India is extremely difficult because of the multiplicity of factors involved. It is not a small area, unit or group that is involved. It is enormous in size and variations. Further it is not a monolithic set-up as in dictatorial regimes, but is a democracy with its large freedom of thought, speech and action characteristic of this way of life. The States with their linguistic base have considerable autonomy. But there are a number of compensating factors the most important of which is a hoary civilization with certain high traditions of liberal religion and philosophy forming the backbone of the nation.

Among the factors that mould the future are the past and the present; they provide the momentum and tradition. All the same there can be unforeseen events that shake the foundation and create new situations. Because of rapid communications the world has in effect become small and incidents are becoming more and more global in their effect. Famines, plagues and pestilences have largely been abolished. Because of the rapid means of communication and transport, improvements in agriculture and other factors, famines despite the growing population do not exist in their original rigour. Thanks to the advances in science and medicine, plagues and pestilences do not raise their ugly heads as they did a generation earlier. The idea of a Welfare State has generated some minimum security. But there is always the possibility of war, small or large. A modern war is highly expensive in men and material and can be devastating and impoverishing. At the same time this danger to the national life of a democratic country brings about a unity of minds not easily secured otherwise. War is a national danger but it does bring out frequently the best in the nation's life.

When our nation obtained Independence after long struggle, suffering and sacrifice, the momentum continued and people including administrators seemed to be dedicated to forge a united and happy and strong India. This seemed to have lasted for about 10 years. But with the taste of power and to some extent money, twin sources of corruption, the morale and grace seem to have gone down during the succeeding 10 years. Just as in physical laws there is equivalence between mechanical energy and heat and they are interconvertible, similar equivalence seems to exist between money and power. Those who have money have tried to convert it into power and those who have power to translate it into money. In this process and effort the country as a whole has been handicapped and its progress crippled. It is difficult to estimate the damage, but it could be appreciated by comparison with other able countries like Germany and Japan that have built themselves up from a state of devastation and serious loss by hard work during post-war years. Certain well meant developments have gone the wrong way. For example controls have been abused on a large scale and have become nasty brakes affecting the law abiding and the progressive, without controlling the unlawful and the wrong elements, because the average man anywhere is not very much above corruption and power corrupts. But the nation, after an unpleasant experience of these, is changing its attitude slowly. There is strong move to rectify this trend. As I have already mentioned India has strong traditions of religion and philosophy. According to these, movements are in waves having crests and troughs. We have been long enough in troughs, the wars have shown up our weakness and strength and we are now moving towards crests. There is move towards correct norms of democratic life and public behaviour. In our tradition it is called Dharma. Every individual should have the twin ideals of elevation of the self and good of the world or nation in the narrower sense. The first cannot be at the sacrifice of the second because it is included in the second. Here comes the principle of sacrifice of the small self for the larger self of the community. Since the nation is maturing in democracy the principle of sacrifice will be more and more fully re-established and an impersonal attitude will be adopted in matters concerning the affairs of the Nation and of the world. I may mention here another notable principle of our ancient tradition. Money should be entrusted to a person who has no personal need or use for it and will, therefore, be an efficient trustee. Similarly, power should be entrusted and handled by persons who have no personal need and use for it for personal gain. Unfortunately, in a youthful and impulsive democracy, the power-crazy clammer to seize power and money-crazy amass wealth, with the result these are abused and the nation suffers. The only corrective is to reunderstand and

follow the path of our ancient national wisdom. As an example it is becoming a practice that at critical times of social disaster when considerable money and responsibility are involved, the relief work is entrusted to the Ramakrishna Mission. Many more such institutions should be encouraged and developed so that the Ramakrishna Mission spirit pervade and eventually inspires the country.

There is generally a mistaken notion that devotion to science does not generate the mental attitude for the ideals of dedication and service. It may be, therefore, significant here to recapitulate the objects of the Royal Society which was founded in U.K. more than three hundred years ago and has continued to work as a leading scientific society in the world. They have been stated as "the promotion, by authority of experiments, of the sciences of natural things and of the useful arts, to the glory of God the Creator and the advantage of the human race". Here also the twin ideals of service to God and service to fellow beings are emphasized and it is these more than power and economic advantages that have been the cause of the very rapid advance of science.

During the coming years we can expect a determined effort to consolidate our positions in all our various undertakings in the field of science and technology and industry. This is essential for steady progress. As already pointed out we have been expanding and producing larger numbers and quantities. Emphasis on quality has been lacking and so also on efficiency if we use world standards. There has been public awareness of this, though few have the energy or the opportunity to actively improve the position. Those who come to the top in a democratic set up may not always have the ability to do this; in the alternative they should have the humility and the sincerity to look for talent and take correct help. The need to keep up party strength leads to compromise which affects efficiency. In many cases the discovery of the right person is difficult. Men in power expect to be courted for patronage. A really capable man cannot always be discovered by this process. The less competent, but less self controlled have a great tendency to come up. This has been happening so often in the past that it is likely to continue in the future. But national emergency may produce the correct climate that ordinary times do not; in periods of trial correct discrimination and objectivity may be expected to develop.

Universities

As already mentioned the universities have increased enormously in number during the past 15 years. But the quality of most of the

new universities has not been high in teaching or research. Because of this increase, old and established universities do not receive adequate assistance; they also tend to stagnate and even go down. As a consequence there is an overall lagging behind which amounts to lowering of standards when compared to advancing universities in forward countries. This has been understood by our educationists, and our national leaders, and the U.G.C. are crying halt to this numerical increase and qualitative decrease. More attention has been focussed on universities, as the primary training ground for future scientists and technologists. We can, therefore, expect marked improvement in the following directions:

1. An improvement in the quality of teachers with an increase in their emoluments and their status. Compared with other walks of life teachers at present occupy a lower level which is not good for the nation. Often the question has been asked whether this change can have an immediate effect and whether the same people will not continue in spite of increased emoluments. The fear is justified. But first things must come first and the effect can be felt only in the future.

2. The laboratories and teaching and research equipment will be improved. This will be done by liberal import of essential materials and more by encouraging indigenous production. Our leaders realize the handicaps under which universities suffer. Though slow in giving effect, the change is sure to come. Indigenous manufacture is in the hands of active groups and we can hope that with devotion and careful discrimination the essentials could be produced in the country.

3. With the help of American aid, the U.G.C. has launched on plans for improving the efficiency of teachers by holding summer schools, for the publication of good textbooks for schools and colleges and for the production of primary teaching aids. Unfortunately, much of our resources are drained by war of defence and much of foreign aid has to go for the fight against hunger because we do not produce enough food. Little is left for the war against inefficiency, illiteracy and diminishing standards. We can hope that with some years of peace and with planned development it will be possible to improve our science education all round.

4. An important and distressing feature in our academic institutions has been pointed out time and again. Many young men and women who have been active in research and have made achievements, after a particular stage and especially when they have better facilities and are expected to help others,or provide leadership, slacken

and do little original work. Some do nothing more than look after their personal affairs. Many others take interest in general politics or at best in trivial management which can normally be relegated to others. This is sometimes baffling in its proportions and looks incurable. Attempts have been made to solve it by offering incentives such as merit awards and merit promotions. These are good to encourage the deserving though there are also serious difficulties, because the agitators and canvassers enter the field vigorously. There is a limit also to monetary incentives particularly for people who have reached top levels and still continue to look for incentives.

It is not uncommon for persons in top positions to say that they have no more promotions to look for and do not have any more interest in work. For them the only cure will be spiritual education. For world's physical goods there is a limit. If one is anxious for more and takes it, another has to suffer and go without. But in the mental and spiritual fields there is an unlimited world to conquer. This conquest is personal and does not affect others adversely and it produces real enjoyment. This ideal could be expected if not in industry and business or politics, at least in the academic set up of universities and research institutions. Thus the only long range solution seems to be moral and spiritual. Each man must do his duty irrespective of rewards and work as worship should be considered as enough compensation or reward for ability.

Examination Reform

This has been one of the major problems in education and we can hope that large changes will take place during the coming 10 years. Most of our older universities started as examining bodies and laid great emphasis on examinations. Only much later they took upon themselves some teaching responsibilities at the post-graduate level. Some universities like Madras and Bombay have not yet fully done even this and depend on co-operative teaching by the colleges. But the swing towards teaching has taken place markedly and hence the need for examination reform as an aid to good teaching. Rational and correct examination system is a great puzzle. There are so many factors involved in the assessment of merit of students, that it seems to be difficult to have a faultless system. But much can be done if effective teaching and training of the faculties of students is kept firmly in mind. Examination should be treated as a test match in cricket and provision should be made for creating enthusiasm for tests. Further undue emphasis should not be laid on one formal examination; cumulative results of a number of tests provide better assessment.

But examination reform is fraught with many dangers. One of these arises from the inability of students and the public to appreciate disciplined life and study; strikes have taken place to oppose much needed reforms. The teachers too are not anxious to try out the new systems. It looks as if even a good reform has to wait for a ripe time. However, we can hope the coming years will see the reforms through.

One of the essential features of the future examinations should be a comprehensive test of a student's personality and capacity. The comprehensive examinations may be expensive, but they are necessary. It may be expected that if teaching and examination go together and our teachers' competence and experience improves the expense may not be appreciably more. The test should be not only that of intelligence, memory and capacity for exposition, it should also extend to an understanding of self discipline, a capacity for organization and for completion of work by perseverance. These were probably possible in ancient days when the teacher was closely associated with the students. Even now by constant effort and organization the same end can be achieved with a lesser number of teachers. The development of sophisticated aids may help in this matter.

University Administration

There has been considerable discussion in recent years about university autonomy and model constitution for universities supported by or opposed by a large range of views. Historically a university arose as a community of teachers and students and up to recent times some of them consisted of only these and were self sufficient and quite autonomous. Slowly private munificence came to their help and endowments were received without affecting the set-up. Earlier monarchs also helped munificently and more recently democratic Governments have followed. In most of the advanced countries the original autonomous set-up still continues and so also harmony in university life except when ideological regimes have found need to control universities to some extent. The picture is different in developing countries. The bureaucratic colonial governments had no need to think of autonomy anywhere and under them the older universities had largely official set-up. This spirit and tradition has been inherited and absorbed by the successor democratic governments also and has led to a third important factor in university life, that is administration and some of our major ills seem to arise from this. There has been s ruggle for position and influence. The political party in power naturally desires the university administration to be under their command. The opposition parties find it necessary to undermine it and utilize the students for their purpose. This state of affairs seems to be the major cause

of student indiscipline and unrest. The students also claim a share in the administration. Consequently most of our elders including the Congress desire that politics and politicians should not interfere in university matters. But they do not seem to realize that Government is also a party government and they should set the example. Unfortunately, this is not happening. If anything the situation seems to be getting worse, *e.g.*, the Revised State Universities Act over which public feeling has been considerably disturbed. Unless a rational understanding of the function of universities prevails, they will become instruments of changing Governments and be tossed among political waves. The ideals of universities that they should be centres of learning and light and of peace and harmony will be lost and they will be centres of political agitation instead. Even now the minds of teachers and students are distracted from their ideals, and learning has largely gone into the background. This loss of perspective and of ideals is of dangerous consequence for the healthy progress of the nation. There is greater need now for our Vedic prayers that teachers and students may be protected and be allowed to study in peace.

Centres of Advanced Studies

Universities have dual responsibility: (1) teaching of known knowledge and (2) discovering of new knowledge. Consequently the teachers should be encouraged not only to do good teaching but also good research dealing with subjects of importance. In this matter other advanced countries have been very successful and the original work is a good index of the level of advancement. It has already been mentioned that there are difficulties in the organizatin of science teaching in our universities. The situation is worse in regard to scientific research. During the past few years, the University Grants Commission, Ministry of Education, CSIR and Atomic Energy department have been taking special interest in encouraging research and improvement is naturally expected. However, research tradition is a very difficult one to establish and by a combination of circumstances if this has been established in any place it should be zealously preserved and nurtured. This has been very ably done in England and U.S.A. by the founding of special institutions in universities where special research fields have been developed. Russia has gone ahead in these matters during recent years. Many institutes are in the names of great scientists who have laid the foundations for a particular discipline and tradition, for example, Vernadsky Institute for Geochemistry, Nesmeyanov Institute for Elemento-organic Chemistry. This is with the important purpose of keeping a lighted torch burning better and better.

In India too certain centres have been founded in this manner particularly in Calcutta: Bose Institute, Saha Institute of Nuclear Physics and Institute of Radio Physics. In a different way Andhra University at Waltair and Annamalai University have created several institutes for special aspects of subjects, for example, Geophysics, Nuclear Physics and Marine Biology. In line with these developments and particularly with a view to saving effort and finance the UGC has launched on a scheme for establishing Advanced Centres in special fields of studies. These were intended to be established round scientists or savants of eminence and to consolidate schools that have been developed and that shows possibility of further development. It is still in the experimental stage and probably suffering from "teething" troubles. With adequate fostering care in the hands of UGC and the concerned universities, these centres can become instruments of rapid advance in these specialized fields in our universities and enable them to reach international levels.

Indian Institutes of Techonology and other Institutes

The new technological institutes called I.I.Ts. located in five important centres have many advantages. They are compact and concentrate attention on technology. They have good resources and favourable staff student ratio. But each seems to be tied to some traditions of the foreign countries that aid them. Bombay is aided by U.S.S.R., Madras by Germany, Kanpur by U.S.A. and Delhi by U.K. There is some emphasis on the teaching traditions of the concerned countries. This may be the cause of heterogeneity in the engineers and scientists that will offer to take up technological work for the nation. During the coming ten years they can be expected to get over the initial troubles and settle down to a national pattern. Further, they may concentrate on the technological side even in doing the advanced studies and research in chemistry, physics and mathematics. It is difficult to forecast about the development of the regional engineering colleges, because of local influences. But their importance is bound to grow and they will take their places along with the I.I.Ts. The proper development would be to elevate them to the level of I.I.Ts. in every respect.

In medical colleges and institutes in our country, for a long time the main interest was in teaching and hospital work and medical practice. Following the modern developments in medical sciences, greater interest is now being given to specialization and original work. Under the new arrangements ICMR is making great progress in removing this backwardness and the coming years will see the rapid spread of research in the medical sciences.

The Directorate General of Public Health is also providing liberal scholarships for post-graduate training in medical sciences. Besides this, institutes should be started for teaching and research in Basic Medical Sciences offering scope for the full development of subjects like Anatomy, Physiology, Biochemistry and Pharmacology which in their own right are definite disciplines and to which non-medical scientists can also contribute fully.

National Council of Educational Research and Training (NCERT)

A point that should be emphasized in regard to Science Education is the recent organization of the NCERT. This is intended to produce good teachers and improve the teaching of science or and hasten the progress of education. Regional Colleges of Education with special facilities have been started in different parts of the country. The important point is that they are science oriented and are intended to develop and improve the teaching of science in schools and colleges. The Council has also a programme of Science Talent Search among young students and is helping them to develop interest in science in various ways.

National Laboratories and other Institutes

We have already recounted the existence of a large number of large laboratories designated National Laboratories. They are important and liberally equipped. We have already mentioned their weaknesses, and could expect they will be avoided in the new ones. Each laboratory should start as a small unit and grow over a period of years in the size of the structure and staff. In the enthusiasm of political freedom and great desire to do well and make up for our backwardness in science and technology the older ones were even at the start made too big and staffed in a hurry and they have become unwieldly and diffuse. This can be avoided when new ones are organized. When they develop by stages their function will also be clear and they will pull their weight efficiently. The existing large ones have been subjected to a great deal of criticism by the public and by reviewing committees. But these criticisms should be followed up by persistent action. Most of the laboratories are staffed by university men who except for a few have not adapted themselves to large project work and in a way have resisted it. There is a tendency to get the high emoluments available in the National Laboratories and use all the rare facilities for what may be described as *ad hoc* academic studies. This is bound to go when the authorities and the public exert themselves and the laboratories will turn out to be centres of applied research of national importance.

Among the public and even among many scientists clear notions of research do not prevail. Research has a large spectrum, and all the various parts are important and useful. There should be no wrong notion that one is more important than another. First, we have the time honoured fundamental research which reveals the secrets of nature. Highly trained scientists are needed and they should be intimately connected with growing men and ideas. This is best provided in universities and only a few select people who are specially dedicated to the persuit of knowledge for its own sake and who have no ambitions for riches and power are suited for this avenue. Then at the other end of the spectrum we have laboratories attached to industries which deal with day to day problems of production and maintenance and improvements. There is a great deal of money in this work and the scientists get paid well, and sometimes become managers also. But this does not produce revolution in technology. In between there is a large and vital area of project oriented research which deals with large projects of national importance and applies the principles of science. Revolutions in Industry and sometimes in science also are created here. But the choice of the teams of workers is important. In certain areas like glass and ceramics and atomic energy we have done this successfully. In the coming years this region of project oriented research will have to be encouraged and deliberately fostered.

Administrative Re-organization

There is urgent need for the re-organization of the administration of education, science and technology. At a time when our science and technology and industries had not developed it was all right to club them together. There has been a general tendency to ignore one or the other. Now that the responsibility has become large and they require rational separation. The CSIR has also been expanding in an effort to embrace practically all aspects of science and technology with the consequence that the desired results cannot be obtained. Concentration as opposed to diffusion is the key note of any success, not only in Yoga. Technology and industry will have to be placed under a Ministry of Technology and this will take over the CSIR and be responsible for the National Laboratories and the Industrial Research Associations, National Research Development Corporation (N.R.D.C.) and the Atomic Energy Department. The Ministry of Education and Science will be able to manage not only universities but also all institutions and organisations connected with fundamental research such as observatories and surveys.

The question of centralization and decentralization has been a difficult one. Mere big size has been sometimes considered to be a sign

of strength; it is in reality frequently a sign of weakness unless it has parts which are equally strong. Further beyond a limit, size is inimical to efficiency because one of the major casualties is the lack of clear cut objectives. Decentralization is now becoming the urgent necessity so that there can be greater efficiency and quickness of despatch. The ideal will be decentralization with essential central co-ordinating link.

As already stated Defence needs its own scientific laboratories to satisfy its requirements and they have been increasing in number and extent. Other executive departments also need scientists of their own in order to identify the problems where science could help and to advise on its applications in the activities of those departments. Indeed, even now some of them have, for example, Aviation. In this connection the Road Research Laboratory at Delhi and the Buildings Research Laboratory at Roorkee should be transferred to the Ministries that use them, so that there will be greater contact between research and its applications. Of course, Government scientific institutions should conduct their work with the objective of utility and only then practical benefits will accrue. Frequently these extend to industries when they assume responsibility of exploiting the results of research.

The efficient conduct of scientific research in all its aspects has been demanding world attention. Important committees have been working on it in U.S.A. and U.K. Though it is difficult to be definite in making recommendations, some guidelines have been indicated. Applied and developmental research are expensive requiring long experience and large scale and costly equipment and they should be oriented towards definite objectives of national importance. Special institutions maintained by Government and industry are mainly responsible for them. Basic or Fundamental Research done in universities could be unfettered for several reasons. The first is that they have education and training as main objective. They are comparatively less expensive and, therefore, sometimes called "Little science". The modern trend is to do with as little material and time as possible; micro and ultra-microscales are employed. The principle is that what reactions could be obtained using a million molecules could also be done with a thousand. This reduces expenditure though somewhat costly electronic equipment have come to be needed here also. But there is another value of fundamental research besides the ideas it generates and the applications it fosters in various directions; the value is aesthetic and spiritual. It affects the whole intellectual life of the nation by affecting its way of thinking and the standards by which its actions and intellectual productions are judged. This way it has

a large intellectual and cultural value and keeps the mind and intellect of those engaged in it exercised and healthy. The case for generous support for pure and fundamental science in universities is thus very strong and it needs only a small part of the nation's total income. Any neglect of it will weaken the most active and vital part of our intellectual life which is generally regarded with pride and respect by the nation. Further there has always been a close connection between basic science and industrial growth; where there is industrial growth there is basic science and *vice versa*. Examples are provided by U.K., Germany, U.S.A., U.S.S.R. and Japan.

Industries

During the past 15 years we have touched modern industry at many points. But we have largely depended on foreign know-how. This has not given us the success that we would like to have. Initially it may be an advantage, but it does not provide strength and stability. During the coming years indigenous talent and technical know-how will have to be developed; I am sure there is enough of potentialities.

Our engineering industries have gone ahead to a considerable extent and may be expected to be in good shape in about 10 years. Our textile and sugar industries are even now all right. On the other hand our chemical industries are still in the developmental stage. The basic bulk chemicals are expected to be developed in the coming years. This will help the drugs and dyestuffs industry to be fully India oriented. We now import most intermediates. This import should cease since they consume foreign exchange. The development will require a great deal of effort on the part of Government and scientists. We have done reasonably well so far and hope it will be better in future.

Some revolution should be effected in our industries based on agricultural products. We have many such industries such as sugar, textiles, jute and oils. But the utilization of by-products of these industries, *e.g.*, bagasse and molasses and cotton waste, and utilization of somewhat inferior grades of materials has not received full scientific attention and this will become important in the near future, because it will not only reduce the cost of the main products but will add to our resources.

We have to give adequate emphasis to the question of know-how and the development of advanced science to the required extent for a very important reason. Not long ago eminent scientists from abroad

used to advise India and other under-developed nations on the use of products of advanced technology so that they could rapidly improve the condition of the common man and not to worry about the development of advanced science which can come later. This was also the view of many leaders in India. They used to argue that for driving a motor car or tractor or aeroplane high level science is not needed. This idea naturally has come to be applied for defence needs besides industries and agriculture. The danger in this view is obvious particularly at this time of our national crisis. Besides driving the car, tractor and plane we have to maintain them efficiently and more important is that we should make them also. If we value independence and value our special way of life we cannot depend on aids and imports only and continuously. We should have the scientific capacity to produce the essential needs for our agriculture, our industries and our defence. The most important is that we should develop scientists of the right calibre and devotion.

Directorate of Technical Development, N.R.D.C. and the Public Sector

During the Second World War the Indian Government had to organize supplies for the war effort. A Director General of Supplies was appointed in the Ministry of Industry and Supplies. The first post-war Director General was one of our distinguished scientists Dr. J. C. Ghosh, who headed very responsible positions before and after this assignment. He was aided by a number of other eminent men and many industries were developed. Later the set-up was continued under the different name of Scientific Adviser and his office grew in importance with a number of senior scientists dealing with the expanding industries of various types under the private as well as public sector. In order to meet the increasing demands, more recently in its place the Directorate General of Technical Development has been established and they hold a key position and large responsibility and on them depends largely the success of our programme of industrialization.

Till after the Second World War all industries except explosives and military drug stores, were private. Railways were the first to be taken over under the public sector, but this happened even earlier in stages; road and air transport have come next. Now most of the large industries are in the public sector (*e.g.*) iron and steel, engineering industries, power supplies, fertilizers, antibiotics and synthetic drugs. There are big hotels now in the public sector. Big Atomic power stations are also coming up. This has required a great deal of industrial administration under Government auspices, and has raised the controversy regarding efficiency of private *versus* public undertakings.

There seems to be no doubt that for large concerns like steel and fertilizers and engineering works in India, Government alone has the resources for quick organization. But along with it come the delays, lack of individual responsibility and lack of economy proverbially associated with such public undertakings. Traditional stories are current in all parts of India that public responsibility is no man's responsibility. As we mature in democracy this attitude will change and better record and out-turn will be possible. Private sectors encouraging merchant "princes", have also their defects though they can show greater efficiency in regard to quickness and economy. But in a Welfare State with its labour laws and control over commodities, finance and imports and exports, the private sector has also lost much of its advantages of initiative and quickness. We may, therefore, expect that both these sectors will work on a general and common pattern which will be rational and efficient from the point of view of the country and the community and the distinction between public and private sector will be only nominal. In view of these developments even secret scientific and technological work connected with defence could in future be entrusted to industrial firms.

Soon after Independence our NRDC was organized on the model of the same in U.K. It was intended to promote the commercial exploitation of patent rights for inventions derived from publicly supported research mainly of CSIR and associated laboratories and sponsored research in universities. This it has been doing. But in U. K. its functions have been expanded to include the promotion of the development of inventions in the public interest whatever their source and their subsequent commercial exploitation. They have also been given certain powers of initiative to take part in and even to sponsor applied research which might lead to the development of new techniques in industry, besides industrial development. For doing all these additional financial resources have been added.

Coming to the responsibility and influence of scientists the position is expected to change. There was a time when in private industries the industrialists had their way and the scientists and engineers carried out instructions. This was all right in simple units or where there was monopoly. Later on scientists have played a far more important part and have got into managerial positions also. But in the public sector where there is no doubt monopoly, we seem to be still in the earlier epoch. Civil-service managers seem to decide the policy which is usually stated to be taken at higher levels and in many cases they are based on foreign "know-how" and dictation. The large number of scientists in the industry and even those in the committees seem to have little say on the decisions; generally their advice is not important.

This practice seems to be slowly going out, but probably too slowly to make an appreciable effect. The frequent complaints that our products cost much more in the country than the world market price and our production efficiency is lower, are cases in point and their causes should be removed. Means will have to be found, not necessarily by paying higher salaries, but by making the scientists feel that the industry is their concern and that the technological "army" should have as much efficiency and purposiveness as our fighting army at the frontiers. Formation of advisory cells and discussion groups in which the workers take part may give a sense of belonging.

Will the development of science and technology adversely affect spiritual India ? This is a question posed by many enlightened visitors from Europe and America. There is a feeling that already the scientists and technologists of our country have ceased to be interested in matters concerning religion and spiritual life. It is well known that in the west the rise of science has seriously questioned religious faith and a continued clash has existed between science and religion. This is also considered to be at the bottom of the tragic misapplication of science for human destruction. But the situation is different in India; there is no conflict between science and spirituality. From time immemorial Indian religions and philosophies have been welcoming all discoveries of science and have been using scientific knowledge and ideas. Our religions not only pray for the good of human beings and their prosperity, but also of all living things. But science and technology, wealth and prosperity in themselves do not provide the goal of human destiny. They are good means and should be used effectively to reveal the divinity in man. There can be a fear that wealth and comfort may create obstacles in the way by making life too complex and too difficult and distracting, to allow people to think of God and religion. But the long religious traditions of India and the religious atmosphere will make this impossible and India will recapture its ancient greatness. Because of the application of technology people will have more leisure and convenience and they will be able to devote them for the development of the mind and the spirit.

There is a scriptural saying "Just as a candle cannot burn without a fire, so man cannot live without a spiritual life". Besides, the material benefits that science and technology can offer to its citizens in future India, there is something more significant. It is in the all important art of living, in the process of man's understanding of himself and in the subtler and deeper realms of the mind and spirit. This can be expected according to our past traditions in which any change and any improvement in the external conditions and facilities have been turned towards spiritual elevation and perfection.

Another important aspect of Indian culture and tradition is the liberal attitude towards religion and catholicity of outlook. "Truth is one, but sages call it by various names" has been the guiding doctrine from the earliest days of Indian history. This has been so fully retaught and relived in recent times by Sri Ramakrishna, Swami Vivekananda and their followers that it has really laid the foundation for the new renaissance in India. It is fully in tune with the spirit of science, that is international and universal. India has correctly become a Secular State emphasizing this attitude. It should not be mistaken for negation of religion, but only stands for equality for all religious paths. All these have produced a climate not only for a cohesive and modern nation, but also for a modern scientific and technological nation emphasizing the equality of man and the equality of all avocations. In science and technology it will be competence, capability, originality and devotion to science that can count for his status and responsibility and not any other consideration.

Science Policy in India

The spirit of India is embodied in the concept of the "Secular State" that the Union Constitution has given itself. As already explained it is not intended to be an irreligious state, but a state without religion imposed by it. It may encourage a real spiritual religion with a catholic outlook. Another aspect of it is the scientific policy which the Parliament has adopted in a definite resolution. This resolution gives a place of honour to scientists and seeks to associate scientists with all aspects of planning and development. By this India has become wedded to science and technology, not only for the purpose of the physical goods and power that they can give, but also for the scientific spirit and way of life which will solve many problems of life and society objectively without fear or favour but with good feeling and wisdom. The responsibilities of a modern government are increasingly large. It is no longer only protective, concerned only to see that wrong things are not done, and that law and order are maintained, but also developmental, increasingly concerned with the promotion of worthwhile and constructive schemes. It is in this more positive role that the pursuit and promotion of science comes in for the nation's advantage.

The number of scientists in our country is large and is growing not only numerically but also in power and influence. As in other countries here also they have formed a Scientific Workers' Association which is intended to organize them for the cause of science and for their own uplift. The two objectives they have formulated are (1) to look

after the interests of scientists and scientific workers and (2) to do all for the advancement and proper utilization of science for the welfare of the community and to see that the results of scientific labour and achievement are not abused. Though this association has not achieved as much as organized industrial labour, its influence is bound to grow in course of time if properly directed. Even labour unions have now come to realize that they not only have responsibility for their unions themselves, but also have a larger responsibility to the society of which they form a part. The more enlightened scientific workers could be expected to place the country and community first and themselves after. They could overcome the trade-union attitude and give freely and abundantly of their rich capacity as enlightened leaders of the nation.

Relation of Pure Science and Applied Science

There has been in recent years considerable discussion of this subject and it has generally been felt that the distinction and delimitation are difficult. Many scientists have been good in both and have been able to see that their discoveries are put to practical account. But many others have been indifferent to utilization. History reveals numerous earlier discoveries being put to practical use much later by people other than the discoverers. In general, the two aspects seem to depend on different attitudes, talents and capabilities. The former depends on an urge to investigate, understand and describe natural phenomena, whereas the latter depends on a desire to control nature using available knowledge. The men of thought who have profound insight into nature and ask the question why and how things happen seem to be different from the men of action who are alert, enterprising and ingenious and ask how knowledge could be used. They are obviously complementary to each other. However, both require, full training in sciences because no one can apply science if he does not know it. Not long ago the discovery and its utilization were matters left to individual enterprise and in some cases to private industrial concerns and the time lag between the two was large. But the problem of utilization has become urgent and important because most scientists are now maintained by public funds in the expectation of tangible and useful results. Therefore there is need to bring the two types together with a common purpose.

The relative importance of the two aspects of science and their value has also been discussed. There seems to be an impression that discoveries in pure science are valued more than their application to technology. There is no justification for this. In earlier years,

most scientific work was of applied nature and what is called pure science is a later development. Faculties in either line have received appreciation, frequently practical application provides more tangible rewards. It is natural particularly in underdeveloped countries to place this emphasis on applications. But, as already mentioned knowledge of facts should be clearly available before application is possible.

Essentials of Successful Scientific Research and Research Organization

This is another topic of earnest and frequent discussion. Primary emphasis has been laid on the gathering together of a community of scientists having complementary skills and talents and making them work in an atmosphere of mutual understanding and respect in a framework capable of mobility. Due importance should be given to the dedicated scientist who is also imbued with faith in his mission and capable of leadership. There is a broad spectrum among scientists. Some are narrow specialists quite uninterested in human relations and this type has done very well in the past. But in the present where team work is essential they are unsuitable as leaders, neither are those who are good in human relations but have no deep and personal understanding of science at its highest levels. Further, no amount of organizational perfection can replace devotion of the leader and the rank of scientists, not certainly the administrative stroke of the pen or lavishness in budget.

Much has been done recently to promote democratic equality and to provide incentive of various kinds. Administrative set-up has been devised to provide mobility and to foster effort and to exercise vigilance over avoidance of waste and extravagance. All this will be of no avail unless it is backed by courage and skill and intense faith at all levels. The objective of scientific research should be placed much higher than the gathering of wealth and comfort. It should be the real pleasure of the pursuit of knowledge and service to fellowmen. Probably, it should be viewed as a "Sadhana" for developing the mind and spirit to get a view of the intimate reality of existence. In fact, there is need to understand that creative science is one of the greatest activities of the human mind and spirit. If this faith could grow with most of those who work in science, the status of the scientific community will rise remarkably.

Budget for Science

Frequently there are discussions on the budget allotted by Government for scientific research. Two obviously important sides to the

question have been widely debated. One view, emphasized by most scientist administrators who are responsible for large organizations, is that the money allotted is not enough and compares very unfavourably with that spent by other advanced countries. They contend that if India wishes to have a sound base of science and technology, useful not only to industry but to all fields of production affecting the economy of the country and its defence, the expenditure on research and development including defence science should not be less than one per cent of the gross national product. They also favour some kind of unfettered expenditure as in industry and at the same time plead that research is difficult to assess regarding its output and results and should not, therefore, be assessed rigorously. The other view upheld largely by administrators and political leaders is that we have increased our commitments to science fairly fast to the tune of over 100 crores of Central and States' budget excluding expenditure on research in universities. Has scientific potential in the country advanced in the same rapid proportion and are the results commensurate with the expenditure? There is no doubt that just as in other human activities science and technology also advance gradually. Make haste slowly is the correct motto here also, and similarly "start small and grow bigger and bigger according to capacity". Since ours is a poor country with a number of rival demands like food, health and education, we should carefully assess at every stage whether any fresh expenditure is justified and will be fruitful. There should be a purposeful way of going forward and of making sure that the expenditure on research and development is realistic. A senior German Professor who happened to visit our country explained that in industry for the same product, the private sector is much more economical and efficient as compared with the public sector. Likewise for the same type of research a University Laboratory is several times cheaper than a State or State sponsored laboratory. There is some importance in this observation particularly for our country with limited finances.

After a conference of scientists held in 1962 it was resolved that a committee should be constituted for the consideration of the allocation of budget for different organizations dealing with sciences in this country. A list of members was also announced. But it has not so far started functioning. It is possible that if it functions it may rectify the imbalance that seems to exist in the development of the various aspects of scientific research.

There is still another point which we should not overlook. Money and materials alone do not secure good research; it is the human element behind them that does. Leadership in this context is of utmost

importance. Not only in war, not only in big business and industry, but also in research there is what is known as "strategy". We have all appreciated great generals who with a small army and limited weapons have over-powered larger ones. Similarly with small resources great men have built up large industries. We can ignore leadership in the field of scientific research only at the peril of the nation's security and prosperity.

Scientific Publications

The large volume of new and original work in all branches of science and its application to technology has necessitated a vast increase in publications. Numerous new journals have been started and published in the country. Just now the total has been counted as 347 science journals; many of them are quarterlies or six-monthly publications. Unfortunately, there is not only duplication but multiplication of effort and expenditure. This has also the undesirable feature of lowering the standard of the publications. For example there are a number of mathematical societies claiming to be national, each publishing its own journal and demanding help from the Government. Similar is the case with Geography. The position may be better with subjects like Physics and Chemistry, but even in these there is a good deal of avoidable duplication. There is urgent need for consolidation and raising the standard of publications. This may be considered to be a difficult matter in a democratic set-up. But, countries like U.K., U.S.A., Canada and Australia have consolidated national journals and have avoided duplication. This should be possible in India also.

The phenomenal increase of research papers has posed world problems of publication and also of their ready use by means of suitable information service. There have been frequent discussions by experts in the field and certain conclusions have been arrived at. The authors of papers and publishers may be satisfied with the present systems of publication though the expense to the nation may be mounting up. But for the user it is very difficult and becoming almost impossible even if he spends most of his time in studying the new publications. They are so many and so voluminous. Abstracting and indexing services are reaching their limits though they have been very helpful. A valuable suggestion that has been made is the use of computor for this purpose; the papers should be directly fed to the computor information service, sorted and supplied to the users. Another, useful suggestion, is based on international co-operation. "Stream-lining" could be achieved if all national journals of composite nature were

re-organized into international specialist journals. If India could rationalize its publications quickly, it will be possible for her to take a lead in the above mentioned organization of specialist journals for the South Asian countries through a system of co-operation.

Academies and Societies of Sciences

An essential help to the progress of science is the organization of academies and specialist societies. Every advanced nation has a national science academy in some form or name. U.K. has the Royal Society, London which is more than 300 years old and has done excellent work for the promotion of science. Similarly, U.S.A. has its National Academy of Sciences, at Washington and U.S.S.R. has the Soviet Academy of Sciences, at Moscow. Besides these each branch of science like Chemistry and Physics and Biology has its national society and journal. Some like the American Chemical Society control the profession and education in Chemistry; in U.K. this function is performed by the Royal Institute of Chemistry.

In our country there are just now three academies each claiming to be all-India in character. They are (1) the Indian Academy of Sciences, at Bangalore, (2) the National Academy of Sciences, at Allahabad and (3)the National Institute of Sciences of India, at Delhi. They were all started in the thirties and have grown and are publishing journals. Among them the last is the most influential and the most representative. Towards the close of the Second World War it was recognized by Government as the premier Academy of Sciences in India and they were willing to grant a Royal charter to it. But this was dropped because of the changes in the Government, consequent upon the grant of Independence to the country. The National Institute has since been getting Government grants for sustaining its activities which include besides discussions and symposia on important subjects, publications, and the award of research fellowships. Though it is modelled and sustained on the lines of the Royal Society, London, unlike the latter, the Institute has not been used by Government for constant advice and framing of their scientific policies. By this lack of co-operation both seem to suffer. There may be problems involved in this recognition and co-operation, but they are not beyond solution. Almost from the beginning the Royal Society in U.K. has been in close collaboration with Government in the organization and utilization of science. It has always occupied a privileged position among the national scientific institutions. Its advice has been sought by successive administrations and it has been receiving large annual Government grants for promoting research. The same can be stated about

the National Academy of Sciences in U.S.A. The U.S.S.R. has gone further and is using its academy as a limb of Government. Every Academician is paid a handsome honorarium for life. Our country could adopt a similar model. There have been efforts to start a new academy of the correct type. But it will take a long time for a new academy to establish itself and develop a tradition. Therefore, taking all things into consideration the National Institute should be utilized by Government in an appropriate manner.

A strong academy at the Centre to advise the Government may also be entrusted with the organisation of the societies relating to the different branches of science. At present there is a multiplicity of societies in a number of science subjects; currently the number of science societies has been counted to be 189. In a few subjects like Chemistry plurality may arise from difference in function as for, *e.g.*, Chemical Society for research and publications of fundamental research and the Institution of Chemists for the organisation of the profession and education. But even this is a weakness; consolidation will mean more strength and utility and can take place with a little effort on the part of those concerned.

There is another big organization called Indian Science Congress Association. It is well known all over India because of the large annual congresses it holds in different parts of the country. It was initiated in 1915 by a number of enthusiastic scientists, many of them British, who were employed in India. It was modelled on the British Association for the Advancement of Science and it has been holding meetings at university centres. General discussions and reading of papers in special sections form an important part of its activities. Besides this there are excursions and social functions where scientists from different parts of India can get together and exchange views. There are no doubt the ceremonial parts and functions of the Science Congress at which V.I.Ps. are present.

Since its membership is liberal and unrestricted, it has tended to draw large numbers. Because of railway and residential concessions to members, possibly far more people gather than are really interested in science or could contribute to its progress. Further, though the British Association on which it was modelled has changed with time and the changing needs, the Indian Science Congress, unfortunately has not. With necessary modification of democratic methods by which efficiency and quality will get their due share of appreciation, the Indian Science Congress may change and be functionally more useful. Recently it has been organizing popular lectures in different parts of the country and has begun to run a journal for the popularization of Science.

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